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INJECTION MOLDING THERMOPLASTIC RUBBER

PDO 6989259, Final Report

J. R. Porter, Project Leader

Project Team:
C. E. Roebuck

Published August 1976

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Thermoplastic rubber molding compounds were investigated to determine the feasibility of using this material for certain configurations. Thermoplastic rubber can be processed directly into finished products, using standard thermoplastic molding and extruding equipment. Three series of material, all from the same manufacturer, were evaluated. The mold shrink factors, molding conditions, and possible applications for each series were evaluated. Molding parameters were established, and a relationship of these parameters to mold shrinkage was determined. The results indicated that the shrink factor depended on the series of material more than on the molding conditions. It was concluded that thermoplastic rubber can be easily processed in conventional thermoplastic equipment.

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TABLES

SUMMARY

Thermoplastic rubber molding compounds are relatively new in the molding industry and little processing information is available. Unlike conventional rubber, thermoplastic rubber can be processed directly into finished products, using standard thermoplastic molding and extruding equipment. It combines, to a large degree, the part characteristics of vulcanized rubber with the rapid processing advantages of thermoplastics.

The purpose of this project was to determine feasible methods of processing various part configurations and to establish mold shrinkage requirements. Primary interest was the evaluation of Uniroyal's TPR (thermoplastic rubber) because it had been selected for possible use as a *Potting Boot* material. No previous work is known to have been conducted for this purpose.

The first phase of the evaluation consisted of molding different series of thermoplastic rubber under different molding conditions. This established a relationship of mold shrinkage versus molding conditions.

The second phase activity consisted of injection molding a Potting Boot, ER302. The Potting Boots are used as molds to pot electrical cable connections and are discarded after the potting compound is cured. The Los Alamos Scientific Laboratory (LASL) evaluated the Potting Boots and reported that the potting compound adhered to all of the TPR materials. They are currently re-evaluating the potting concept for possible material change or complete redesign. No additional activity on this project is anticipated at this time.

DISCUSSION

SCOPE AND PURPOSE

Thermoplastic rubber is one of the more recently developed materials in the molding industry, and little processing information is known about this material. This project was designed to provide shrink factors, molding conditions, and possible applications for Uniroyal's TPR, a thermoplastic rubber molding compound. The shrink factors are used to provide conceptual guidelines for design and fabrication of future injection molds.

One application investigated was the injection molding of a Potting Boot, ER302. The boot was used by LASL to evaluate the material from a functional standpoint and to determine if the material was satisfactory for use in certain applications.

PRIOR WORK

No previous work is known to have been conducted for this purpose.

ACTIVITY

Phase I. Mold Shrinkage

Molding Conditions

Three series of thermoplastic rubber were molded and inspected to determine mold shrinkage. Relationships for the various molding conditions versus mold shrinkages were established. The three materials were Uniroyal's TPR 1600, TPR 2800, and TPR 1900. Each series was molded in a mold cavity which measured 1.994 inches wide (51.1282 mm), 1.999 inches long (51.2564 mm), 0.251 inch thick (6.4358 mm), and had a 0.350-inch-diameter (8.9743 mm) half-round gate. Approximately 10 specimens were molded at each molding condition for each series to determine the effects of molding conditions on the material shrinkage.

Molding

The specimens were molded on a 20-ounce (536.8 cm^3) H.P.M. reciprocating screw injection molding machine, Equipment Number 25398. Table 1 lists the typical processing conditions used to mold the shrinkage specimens. Specific changes to these conditions and their effects on material shrinkage are shown in Table 2. The shot speed, gate size, and mold venting were critical parameters in the process. Certain conditions, such as

Table 1. Typical Processing Parameters for Molding Shrinkage Specimens From TPR 1600, TPR 2800, and TPR 1900

Parameter	Reading or Range
Barrel Temperatures (°F)(°C)	
Nozzle	395 to 405 (202 to 207)
Zone 1A	375 to 385 (190 to 196)
Zone 1	365 to 375 (185 to 190)
Zone 2	365 to 375 (185 to 190)
Zone 3	345 to 355 (173 to 179)
Mold Temperature	Room Temperature
High Injection Pressure	6000 psi (41.4 MPa)
Low Injection Pressure	12000 psi (82.8 MPa)
High Injection Time	9 Seconds
Low Injection Time	50 Seconds
Back Pressure	150 psi (1.03 MPa)
Clamp Pressure	400 Tons (3.56 MN)
Injection Speed	10 (Slow)
Extruder Speed	40 rpm
Cushion	0.25 to 0.5 inch (6.4 to 12.8 mm)

Table 2. Molding Conditions Versus Mold Shrinkage

Condition	Material: TPR 1600, Line Number 1	2	3	4	TPR 2800, Line Number 1	2	3	4
High Inject								
PSI	3000	3000	4500	3000	5250	7500	7500	7500
MPa	20.68	20.68	31.02	20.68	36.19	51.7	51.7	51.7
Seconds	8	8	8	8	8	8	12	12
Low Inject								
PSI	7500	7500	7500	4500	7500	10500	10500	12000
MPa	51.7	51.7	51.7	31.02	51.7	72.38	72.38	82.72
Seconds	60	120	120	120	90	90	90	90
Shot Speed								
1 to 10	10	10	10	10	10	10	10	10
Clamp Closed								
Minutes	3.0	3.0	3.0	3.0	2.0	2.0	2.0	2.0
Average Thickness								
Inch	0.2490	0.2500	0.2495	0.2480	0.2435	0.2445	0.2445	0.2455
mm	6.384	6.410	6.397	6.358	6.243	6.269	6.269	6.294
Shrinkage								
Inch/Inch (mm/mm)	0.008	0.004	0.006	0.012	0.030	0.026	0.026	0.022

Table 2 Continued. Molding Conditions Versus Mold Shrinkage

	Material				
	TPR 1900				
Condition	Line 1	2	3	4	5
High Inject					
PSI	6000	7500	5250	5250	5250
MPa	41.3	51.7	36.19	36.19	36.19
Seconds	9	9	9	9	9
Low Inject					
PSI	12000	12000	15000	15000	15000
MPa	82.72	82.72	103.41	103.41	103.41
Seconds	50	50	50	90	20
Shot Speed					
1 to 10	10	10	10	10	10
Clamp Closed					
Minutes	1.5	1.5	1.5	3.0	0.75
Average Thickness					
Inch	0.2460	0.2460	0.2472	0.2471	0.2440
mm	6.307	6.307	6.338	6.335	6.256
Shrinkage					
Inch/Inch mm	0.020	0.020	0.015	0.015	0.028

fast shot speed or large gate size with insufficient venting, caused trapped air to burn areas last to fill. Reduction in the filling time caused knit lines or unfilled parts.

The TPR parts were prone to form delamination, sinks, or dimples in the gate area. A process capability study would be required to optimize the process and eliminate the visual defects. The study could also indicate that redesign of the gate is required to improve the visual appearance.

Typical Material Properties

Table 3 compares the material properties of the three series of Uniroyal thermoplastic rubber. The most noticeable difference in the materials, other than color, is the hardness. TPR 1600, with a Shore A hardness of 65, can be compared to the hardness between an automobile innertube and tire tread. TPR 2800 and TPR 1900, Shore A hardness of 87 and 92 respectively, are considerably harder but well below the plastics range. For each series or hardness of TPR, three grades are available: natural, black-stabilized, and white-stabilized. For example, within the TPR 1600 series, TPR 1600, TPR 1612, and TPR 1622 are natural, black, and white respectively. The same designation follows for the other series.

Phase II. Potting Boot

The Potting Boot, ER302, was designed by the Los Alamos Scientific Laboratory (LASL) for possible use in certain applications. The Design Agency proposed that the parts be injection molded from TPR. The parts are used as molds to pot electrical cable connections.

Uniroyal TPR material was selected principally because preliminary results indicated that the potting compound would not adhere to the Boot. The TPR Potting Boot would also be inexpensive, easily removed, and discarded after use. This concept would eliminate many expensive metal molds which require disassembly and cleaning after each electrical connection is completed.

Molding Conditions

A Potting Boot, ER302, Mold insert was designed and fabricated for the General K-3070 mold base. Parts were molded from each grade of TPR on the 1.30-ounce (34.89 cm^3) New Britain reciprocating screw injection molding machine, Equipment Number 24092. After the general processing parameters had been determined, only minor changes were required to establish a suitable process for the different grades. The general processing parameters are given in Table 4.

Table 3. Typical Material Properties

Property	Material TPR 1600	TPR 2800	TPR 1900	Reference ASTM
Specific Gravity	0.88	0.88	0.88	D-471
Hardness, Shore A	65	87	92	D-2240
Tensile Strength (psi) (MPa)	650 (4.48)	1350 (9.30)	1900 (13.09)	D-412
Ultimate Elongation (Percent)	210	180	250	D-412
100-Percent Modulus (psi) (MPa)	550 (3.79)	1250 (8.61)	1850 (12.75)	D-412
Tensile Set at Break (Percent)	10	30	50	D-412
Compression Set After 22 Hours				D-395B
Percent at RT	25	30	40	
Percent at 158°F (70°C)	45	70	70	
Torsional Modulus (psi) (MPa)	300 (2.06)	1200 (8.27)	3000 (20.68)	D-1053
Flexural Modulus (psi) (MPa)	1500 (10.34)	8000 (55.15)	20,000 (137.88)	D-790
Bashore Resilience (Percent Rebound)	50	50	45	---
Split Tear (psi) (MPa)	45 (0.31) 140 (0.96)	100 (0.68) 350 (2.41)	100 (0.68) 500 (3.44)	D-470 D-624
Abrasion Resistance (gram/kilocycle)	0.6	0.3	0.4	D-1044

NOTE: Information taken from Uniroyal Chemical Bulletin, Form No. 575-B002A, ASP-3129A

Table 4. Processing Parameters for Molding the Potting Boot, ER302 From TPR 1600, TPR 2800, and TPR 1900

Parameter	Reading or Range
Barrel Temperatures (°F)(°C)	
Nozzle	500 to 510 (260 to 265)
Zone 1	495 to 505 (257 to 262)
Zone 2	465 to 475 (240 to 246)
Melt Temperature	460 to 470 (237 to 243)
Mold Temperature	
Left Side	140 to 150 (60 to 65)
Right Side	140 to 150 (60 to 65)
High Injection Pressure	1000 to 1200 psi (Line) (6.89 to 8.27 MPa)
Low Injection Pressure	800 to 1000 psi (Line) (5.51 to 6.89 MPa)
Injection Holding Time	25 Seconds
Back Pressure	50 to 100 psi (0.34 to 0.68 MPa)
Clamp Pressure	Maximum
Shot Speed	20-25 (Slow)
Clamp Closed	40 Seconds
Extruder Speed	Low
Cushion	5 Percent
Cylinder Size	A

One negative aspect to thermoplastic rubber is that it flashes easily, especially the softer grades. This is particularly troublesome because the flash is very difficult to remove due to the soft and pliable nature of TPR. It is recommended that consideration be given to the mold design and fabrication to eliminate flash where possible. It is also recommended that any additional work with thermoplastic rubber include a process capability study. Such a study was designed for the Potting Boot but was not performed.

Evaluation

The evaluation of the Potting Boots was primarily based on whether the parts would or would not function for the intended purpose. The parts molded from different grades of TPR were sent to LASL to be evaluated. No evaluation, other than visual, was performed at Bendix. The Design Agency evaluated the Boots by potting cable connections and curing them at different temperatures. It was reported that the parts were dimensionally good. However, the potting compound, Scotch Cast 8, adhered to all the different grades of thermoplastic rubber, and the reasons were not determined. The black-stabilized TPR 1612 did perform better than the others, but it fell short of expectations. The Design Agency stated that as a result of their evaluations they are contemplating either a material change or a complete change in the potting concept.

ACCOMPLISHMENTS

Mold shrinkage for Uniroyal's Thermoplastic Rubber (TPR) is dependent on molding conditions and material hardness. Shrinkage relationships for the different series of TPR varied from 0.004 to 0.012 inch/inch (mm/mm) for TPR 1600; 0.015 to 0.028 inch/inch (mm/mm) for TPR 1900; and 0.026 to 0.030 inch/inch (mm/mm) for TPR 2800. Specific changes in the molding parameters and their effect on shrinkage are shown in Table 2.

Potting Boots molded from three series of TPR were evaluated by LASL. Dimensionally, the Boots were acceptable. However, the Scotch Cast 8 potting compound sporadically adhered to Boots molded from each series of TPR. The black-stabilized TPR 1612 was superior to the other grades but it fell short of design requirements. The TPR Boot concept of potting cable connections is currently being reviewed by Los Alamos Scientific Laboratory.

FUTURE WORK

No additional activity on this project is anticipated at this time.

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